

4.0 VENDOR TECHNOLOGIES

Vendor technologies tested during CTSS field activities included the following:

- Krüger, Inc. (pilot unit shown in **FIGURE 4.1**)
- Infilco Degremont, Inc. (pilot unit shown in **FIGURE 4.2**)
- ROCHEM Environmental, Inc. (pilot unit shown in **FIGURE 4.3**)
- F.B. Leopold Company (*see* **FIGURE 4.4** for pilot unit view)
- Micromag Corporation (*see* **FIGURE 4.5**)
- Biochem Technologies, Inc.
- ZENON Environmental, Inc.
- Syracuse University / HSA Engineers & Scientists
- University of Florida
- ETUS Inc. / HSA Engineers & Scientists

A review of the vendor testing conducted during the CTSS field activities is provided below. Vendor-supplied summary reports that provide additional detail on specific processes and scientific investigation design details are provided in **APPENDIX 6**.

4.1 ACTIFLO PROCESS (Krüger Inc.)

The ACTIFLO process is a compact, conventional-type water treatment process that utilizes microsand as a seed for floc formation. The microsand provides surface area that enhances flocculation and acts as a ballast or weight, which enhances settling. This allows clarifier design with high overflow rates (or short detention times).

4.1.1 Process Description

Raw water enters the ACTIFLO system in the first coagulation tank. Here, chemical coagulant is added to destabilize suspended solids and colloidal matter in the influent stream. The intensive mixing provided in this step of the process serves to thoroughly disperse the coagulant into the raw water. Hydraulic detention time in the coagulation tank is around two minutes.

The coagulated water passes into the second (injection) tank where coagulant aid (polymer) and microsand are added to initiate floc formation. This serves as a ‘seed’ for floc formation and development in the next process step. Hydraulic detention time in the injection tank is around two minutes.

The aggregation of flocs continues as water passes through the underflow passage from the injection tank into the flocculation (maturation) tank. In the flocculation tank, a relatively small energy input agitation provides ideal conditions for the formation of polymer bridges between microsand and the destabilized suspended solids. The process is further augmented by the large specific surface area of the microsand provides an enhanced opportunity for polymer bridging and enmeshment of floc particles. Hydraulic detention time in the flocculation tank is around six minutes.

The fully formed ballasted flocs leave the flocculation tank and enter the settling tank. Here, laminar upflow through the tube settlers equipped settling zone provides effective removal of the flocs. Clarified water exits the ACTIFLO system via a series of collection troughs or weirs.

The ballasted floc-sand-sludge mixture is collected at the bottom of the settling tank. The sand-sludge mixture is then pumped to the hydrocyclone for separation. Energy from pumping is effectively converted to centrifugal forces within the body of the hydrocyclone causing chemical sludge to be separated from the higher density microsand. Once separated, the microsand is concentrated and discharged from the bottom of the hydrocyclone and re-injected into the ACTIFLO process for re-use. The lighter density sludge is discharged out of the top of the hydrocyclone and sent for thickening in holding ponds. Both the pond supernatant and the treated water are discharged into the receiving stream, which is the canal.

4.1.2 Scientific Investigation Protocol

There are numerous factors that have a significant or potentially significant impact on the reduction of phosphorus. In such cases one of the main objectives of a scientific investigation design is to screen the large number of potential variables and select the most important ones for detailed analysis. From among the potentially important operational, environmental, and water quality variables, six system variables were selected for detailed analysis. These variables are:

- coagulant type;
- coagulant dosage concentration;
- polymer type;

- polymer dosage concentration;
- pH; and,
- hydraulic loading.

Krüger Inc. developed a one-variable-at-a-time type of testing approach to investigate the effect of the change of individual system variables on the response. Besides the primary system response of Total P concentration, total dissolved phosphorus (TDP), turbidity, and apparent color were also analyzed.

4.1.3 Summary of Investigation Results

The major conclusions of Krüger's conducted pilot study are summarized below:

- 1) From among the investigated cationic polymers, CIBA LT22S appeared to support most effectively the removal of Total P in the chemically assisted sedimentation process. Optimum dosage concentration range was found to be 0.6 mg/L to 0.8 mg/L.
- 2) Testing results suggested that the removal efficiency of Total P was pH dependent. While low removal efficiencies were typically observed at naturally occurring marginally basic pH levels (7.2 to 7.6), higher Total P removals were obtained in the acidic pH range of 4.2 to 5.7.
- 3) Under the conditions tested, the Total P removal efficiency of the two tested coagulants, alum and ferric-chloride, were similar.
- 4) Testing results suggested that under the conditions tested 10 mg/L to 12.5 mg/L ferric-chloride (as Fe) dosage concentration was required to reduce Total P concentrations below the threshold level of 10 µg/L at the south test site. At the North Test Site, 17 mg/L to 21 mg/L ferric-chloride (as Fe) dosage concentration was necessary for similar results.
- 5) Completed testing results suggested that 75 mg/L to 80 mg/L alum (as Al) dosage concentration was required for highest Total P removal efficiency at the south test site. Results with the coagulant alum are not available at the North Test Site.
- 6) In the investigated range of 25 gpm/sq.ft. to 33 gpm/sq.ft., the sensitivity of hydraulic unit loading was higher at North Test Site.

- 7) The reduction of Total P and the reduction of color show little correlation.
- 8) Optimum operating conditions at both test sites are tabulated below:

Test Site	Coagulant Type	Coagulant Dosage (mg/L)	Rise Rate (gpm/sq.ft.)	Polymer LT22S (mg/L)	pH (-)	Average Total P Concentration (µg/L)	
						Influent	Effluent
South	Ferric-Chloride	10 – 12.5	25 – 33	0.80	4.2 – 4.4	16	5
South	Alum	75 - 80	25	0.80	5.3 – 5.7	23	8
North	Ferric-Chloride	17 - 21	25 – 30	0.80	4.2	156	8

4.1.4 Conclusions and Recommendation

Completed test results suggest that the ACTIFLO process can reduce the Total P concentration below the threshold limit of 10 µg/L. However, since these results could not be achieved without adding sulfuric acid and lowering the pH to the 4 to 5 range, the process would not be the first selected option if others could be identified that operate in the more native pH range of the EAA surface waters.

4.2 DENSADEG HIGH-RATE CLARIFIER AND THICKENER (Infilco Degremont, Inc.)

4.2.1 Process Description

The DensaDeg treatment technology is a compact solids contact clarification process.

The DensaDeg clarifier incorporates three integral process zones: 1) reactor zone, 2) presettling/thickening zone, and 3) clarification zone. In the reactor zone, influent water is combined with reactants and preformed solids that have been recirculated from a downstream, presettling/thickening zone. As they flow upwards in a draft tube, the raw water, reactants, and thickener solids are mixed by a turbine. Existing the draft tube, the flocculated mixture, or slurry, moves downwards. Near the bottom of the reactor, a portion of the slurry re-enters the draft tube. This process of internal recirculation produces the optimum slurry density.

Located near the bottom of the reactor is a baffled opening that allows the slurry to exit the presettling/thickener zone of the reactor. As the slurry moves downward through the presettling zone, to a point near the bottom of the vessel, it is forced to make a 180 degree turn beneath a baffle. Due to the density of the solids within the slurry, nearly all are deposited on the bottom of the vessel. Aided by a slow moving rake, which facilitate the release of entrained water, the deposited solids continue to thicken. The thickened sludge is periodically blown down from the bottom of the thickener and introduced by gravity to the holding pond. The supernatant flows upward. Lamella tubes, through which all the supernatant must pass, provide for high rate removal of the remaining solids. A series of weir troughs, located above the tubes, collect the clarified effluent.

The pilot plant is rated for 75 gpm to 100 gpm throughput, which allows up to 10 gpm/sq.ft. surface loading in the tube settler.

4.2.2 Scientific Investigation Protocol

Infilco Degremont Inc. (IDI) tested their DensaDeg high-rate clarification and thickener unit at the North Test Site. The pilot scale testing program was conducted in two segments from October 11, 1999 to November 10, 1999, and from November 28, 1999 to December 12, 1999, respectively. In order to assess optimum conditions for the pilot testing, IDI conducted jar testing of the actual raw water source on October 13 and 14, 1999.

4.2.3 Summary of Investigation Results

- ***Jar Testing***

The purpose of the jar testing program was to assess the effectiveness of different process chemicals on Total P removal. The investigated coagulants were 1) ferric-sulphate ($\text{Fe}_2(\text{SO}_4)_3$), and 2) ferric-chloride (FeCl_3) and alum ($\text{Al}_2(\text{SO}_4)_3$). The results clearly suggested that the efficiency of phosphorus removal versus coagulant dosage follows the order: $\text{FeCl}_3 > \text{Al}_2(\text{SO}_4)_3 > \text{Fe}_2(\text{SO}_4)_3$. The relative removals of total organic carbon (TOC) and color followed this same trend in almost identical ratios to phosphorus removal. Based on the completed jar test results, IDI recommended

the use of the two best performing coagulants, FeCl_3 and $\text{Al}_2(\text{SO}_4)_3$ for the later phase of the pilot scale test.

- ***Pilot Scale Testing – Phase #1***

A 2^3 factorial design was the basis of testing in the first segment of the pilot scale study. The three variables were 1) coagulant type, 2) coagulant dosage concentration, and 3) hydraulic unit loading. Each of these variables was investigated at two design levels. These ‘levels’ were alum and ferric-sulphate for the qualitative variable. Investigated dosage concentrations were 10 mg/L and 20 mg/L for alum, and 20 mg/L and 40 mg/L for ferric-sulphate. The two tested hydraulic loadings were 50 gpm and 100 gpm, respectively.

Besides the primary system response of Total P concentration, TDP, soluble reactive phosphorus (SRP), and total suspended solids (TSS) were also monitored. The response parameters were typically evaluated for 1) raw water, 2) clarifier effluent, and 3) the filtrate.

The results of the first segment of the pilot study suggest a varying performance of the IDI supplied treatment package, which contained the DensaDeg high-rate clarifier and a granular media filter column. In terms of overall Total P removal, the removal efficiency varied from 65 percent to 92 percent. Similar removal efficiency ranges for SRP and TDP were 86 percent to 98 percent, and 73 percent to 91 percent, respectively. TSS removal efficiency showed a wide range of variation. The reported data suggests that the DensaDeg treatment unit removed the investigated constituents with a relatively high efficiency. On the other hand, filtration performance was poor.

- ***Pilot Scale Testing – Phase #2***

The second phase of the investigation was designed and conducted by IDI personnel. IDI prepared and submitted a report on the findings as summarized below:

From among the important or potentially important system variables, IDI has investigated the effect of 1) coagulant dosage concentration, 2) polymer dosage concentration, and

3) hydraulic unit loading. The sole system response was the total concentration of phosphorus in the final unit effluent. While the applied coagulant was ferric-chloride, the type of polymer was not identified in the report. The variables were tested at multiple levels. Hydraulic loading was investigated from 50 gpm to 125 gpm in 25 gpm increments. FeCl_3 dosage concentration was tested at 116 mg/L, 125 mg/L, and 140 mg/L. The polymer dosage concentration was designed at two levels: 0.5 mg/L and 1.0 mg/L, respectively.

Reported research results suggested a relatively good performance of the DensaDeg treatment unit. The average raw water Total P concentration of 165 $\mu\text{g/L}$ (during the study period) could be reduced to 4 $\mu\text{g/L}$ 75 percent of the time. Essentially, any combination of system variable setting provided satisfactory results. Since Total P removal efficiency was 97 percent, even at the highest tested hydraulic loading of 140 gpm, the overall optimum performance of the unit still needs to be determined.

4.2.4 Conclusions and Recommendations

Testing results suggest that the DensaDeg high-rate clarifier is capable of reducing the Total P concentration below the threshold limit of 10 $\mu\text{g/L}$. This high Total P removal efficiency was achieved however with a relatively high dosage of the treatment chemicals. Comparing to competing technologies, the consumption of the coagulant was high. Besides the increase of operation cost, the relatively high dosage of the coagulant (ferric-chloride) will result in the generation of excessive amount of sludge.

4.3 ULTRAFILTRATION (ROCHEM Environmental Inc.)

4.3.1 Process Description

“Ultrafiltration” (UF) is a pressure-driven, separation process where the water to be treated is separated by a porous membrane into a stream of purified filtrate and a remaining quantity of concentrate. The principle of UF is that, in the presence of an external pressure or driving force, liquid flow occurs from the concentrated solution to the dilute solution across a semi-permeable membrane. The pure water (known as product water or permeate) essentially emerges at near

atmospheric pressure, while the waste (known as concentrate or brine) practically remains at its original pressure. In the concentrate are accumulated the suspended solids contained in the water which have been rejected by the membrane.

The ROCHEM modules for UF have been developed specifically for the separation of particles in the sub-micron range from water with high fouling potential. The combination of open channel construction and narrow gap technology with an efficient cleaning method allows for high filtrate fluxes with relatively low energy demand. The easy modification of the free path feed side (distance between membrane cushions) makes possible the application of this module in a wide range of suspended solids concentrations.

4.3.2 Summary of Investigation Results

The Rochem UF unit is a relatively small (sub-pilot scale) unit capable of producing a permeate/filtrate flow of 1 gpm at a 90 percent recovery rate. The nominal pore size of the UF membranes was 0.03 microns. The unit was tested for direct treatment without chemical addition of ENR effluent (Post-STA) water over a four-week period and consistently produced a permeate of less than 10 µg/L of Total P from a feed water varying from 14 µg/L to 39 µg/L of Total P. Results are summarized below:

<u>Testing</u> <u>Date</u>	<u>Feed</u> <u>Total P (ppb)</u>	<u>Permeate</u> <u>Total P (ppb)</u>
10/13/99	14	7
10/19/99	19	8
10/20/99	19	8
10/27/99	15	5
10/28/99	16	<4
10/29/99	15	6
11/7/99	39	5

4.3.3 Conclusions and Recommendations

The results are significant in that it is apparent that UF is capable of producing a treated effluent with less than 10 µg/L without the use of chemicals or the

generation of a chemical residuals side stream (*i.e.*, a so-called ‘Green Technology’). Testing of a larger, pilot scale UF system is recommended.

4.4 DISSOLVED AIR FLOTATION PROCESS (F.B. Leopold Company)

Dissolved air flotation (DAF) is a solids-liquid separation process that transfers solids to the liquid surface through attachment of fine bubbles to solid particles. The phenomenon of DAF consists of three processes: 1) bubble generation, 2) attachment of solids to the bubbles, and 3) solids separation.

4.4.1 Process Description

Before introducing the raw water to the DAF cell, a chemical coagulant and a pH-adjusting agent can be introduced to the raw water. The dispersion of these treatment chemicals is completed in an inline static mixer unit. The chemically conditioned water then enters the flocculation cell where the destabilized suspended solids and colloidal matter start forming aggregates. Mechanical vertical axle gate flocculators are used to supply energy to induce optimum size floc formation. Since the particles are not removed by gravity, their density does not have to be higher than that of water allowing the relatively low dosage of the coagulant.

The flocculated process water flows under a baffle into the dispersion zone where mechanical vertical axle gate flocculators are used and pressurized recycle water is injected. The recycle water - around 10 percent of the total flow – is taken from the final effluent (clarified water) and pumped into a packed tower saturator (pressure vessel), in which 60 psi to 90 psi pressure is maintained. Air is dissolved into the water through the packing. The minimum amount of air required is 8 grams/m³. The saturated air-water mixture is introduced in the bottom of the dispersion cell. Due to the sudden drop of pressure, air comes out of solution in minute, 10 µm to 100 µm, bubbles.

The aerated water enters a flotation tank, where the air bubbles commence to rise. The 9-square-foot surface area flotation tank is designed for a hydraulic unit loading of 4 gpm/sq.ft. These micro-bubbles inherently carry an electrical charge, which allows them to attach to the destabilized floc particles. Three mechanisms of bubble attachment are known: 1) adhesion to the floc particle, 2) absorption within the floc structure, and 3) capture or enmeshment within the floc structure. The micro-bubble floc aggregates float to the surface forming a

stable sludge blanket. The solid content of a steady-state floating sludge blanket is about 2 percent to 4 percent. The float is then removed mechanically with a chain and flight scraper (or surface skimmer) device. The treated or clarified water is drawn from the DAF tank through a number of underflow collectors located near the bottom of the basin.

The on-line instrumentation of the pilot plant include 1) turbidity, 2) pH, 3) ORP, 4) particle counting, 5) flow rate, and 6) saturator pressure measurement and recording.

The DAF pilot unit could not reduce feed water Total P to the desired 10 microgram per liter threshold level. Based on the DAF test results, no further consideration of this process for Total P removal of EAA surface waters is recommended.

4.5 COMAG PROCESS (Micromag Corporation)

The CoMag treatment technology utilizes high gradient magnetic fields for the separation of floc aggregates. The Micromag pilot-scale water treatment unit is designed for up to 20 gpm hydraulic loadings.

4.5.1 Process Description

Raw water enters the system in the first coagulation tank, where a chemical coagulant can be added to destabilize suspended solids and colloidal matter. The dispersion of the coagulant is achieved by mechanical mixing. The chemically pretreated raw water enters an electromagnetic device followed by a second coagulation tankage, where a nucleation aid is dosed. This vessel is also equipped with a high intensity chemical mixer.

The aggregation of flocs continues as water enters the flocculation process utilizing two tanks in series. The two identical flocculation tanks are equipped with mechanical mixers providing a relatively low energy input agitation of the pretreated raw water. A fine magnetic powder (magnetic seed) is added to the first flocculator tank. Throughout the coagulation-flocculation processes, a significant portion of the added magnetic particles get enmeshed into the floc aggregates. These magnetic particles have the property to be magnetized when placed in a magnetic field. The magnetized particles become tiny magnets (magnetic dipoles) having north and south poles.

The magnetic powder dispersed process water enters a second flocculator tank in which, if necessary, a coagulant aid can be added. Similarly to upstream-applied dispersion methods, repulsion forces between particles are to overcome by a low energy input mechanical agitation of the water in the tankages.

The magnetic seed enmeshed floc containing raw water enters the 'heart' of the process, which is the high gradient magnetic separator. On the basis of electromagnetic principles, the generated magnetic field in the separator exerts a force on the magnetic seed particles. On the basis of electromagnetic and centrifugal forces, the phase separation of floc aggregates takes place.

After phase separation, the liquid phase is discharged from the unit as final effluent. Forced by centrifugal forces, the separated solids enter an energized section of the separator. In the de-energized stage of this device, the floc aggregates and the magnetic seed particles can be separated. The flocs or sludge is wasted and the magnetic seed are returned to the first flocculator cell.

4.5.2 Scientific Investigation Protocol

Micromag conducted their pilot-scale testing at both Test Sites from November 20, 1999 to December 21, 1999. A total of 96 samples were collected and analyzed during this period.

The CoMag process incorporates the following steps:

- Magneto-chemical pretreatment;
- Chemical coagulation;
- Addition of finely divided clay;
- Addition of finely divided magnetite;
- Flocculation; and,
- Magnetic separation.

The investigated system variables were: 1) coagulant type, 2) coagulant dosage concentration, 3) bentonite dosage concentration, 4) coagulant aid (Cytec A-130 polymer) dosage concentration, and 5) pH. The system response was the concentration of Total P in the final effluent. Alum and ferric-chloride coagulants were tested. While the dosage concentration of alum was investigated at four levels (5 mg/L, 10 mg/L, 20 mg/L, and 40 mg/L), the dosage

concentration of ferric-chloride was tested at multiple levels (2 mg/L, 4 mg/L, 8 mg/L, 10 mg/L, 20 mg/L, and 40 mg/L). Bentonite was dosed at 12.5 mg/L and 50 mg/L concentrations. The 4 tested polymer dosage concentrations were 0.5 mg/L, 1.0 mg/L, 1.5 mg/L, and 2.0 mg/L. Several pH levels were tested. Hydraulic unit loading was held constant at 10 gpm during the study period.

4.5.3 Summary of Investigation Results

The comparison of Total P removal efficiencies at the two test sites clearly show higher and more consistent removals at the North Test Site where raw water Total P concentrations are an order of magnitude higher than at the South Test Site.

4.5.4 Conclusions and Recommendations

Test results suggest that the CoMag process can reduce the Total P concentration below the predetermined threshold limit of 10 µg/L. Although it is not clearly reported which testing conditions correspond to favorable results, it is likely that the process is economical due to the relatively low dosage concentration and reuse of process chemicals. The process appears to be more suited to treat waters with higher Total P concentration. At low raw water Total P levels, the CoMag process did not prove the capability for consistent Total P removals. The CoMag process may be considered a burgeoning, promising technology; however, no large scale systems are currently in operation. Until system reliability and cost verification can be made based upon full scale operating data, the technology cannot be recommended for further current assessment.

4.6 DOLOMITIC LIME FIXED FILM BIO-REACTOR PROCESS (BIOCHEM Technologies Inc.)

The dolomitic lime fixed film bioreactor (DLBR) process is a biological treatment technology utilizing an indigenous sessile bacteria for the uptake of nutrients such as phosphorus and nitrogen. Dolomitic lime and lava rock layers provide the supporting surface for the growth of biofilm. BTI conducted scientific investigation with pilot-scale prototype at the South Test Site from September 28, 1999 to November 30, 1999, followed by similar trials at the North Test Site from December 1, 1999 to February 15, 2000.

4.6.1 Process Description

Raw water enters the DLBR system into an aeration tank where the incoming water is aerated through a fine bubble diffuser device. The increased dissolved oxygen concentration raw water then enters the first of three reactor cells. Each of the reactors is packed with dolomitic lime and lava rock media, which surfaces support the growth of biofilm layers.

It is hypothesized that the biofilm structure is not a chance occurrence but represents an optimal arrangement for the influx of nutrients. Substrate conversion rates in biofilms are controlled by growth kinetics and mass transport processes. The overall rate of reaction is equal to the rate of the slowest therefore rate limiting step in the mechanism. The following steps may represent the overall diffusion with bioreaction process for nutrients:

- 1) Mass transfer of the nutrients from the bulk liquid to the external surface of the biofilm;
- 2) Diffusion of nutrients from the external biofilm surface to a specific cell in the matrix;
- 3) Adsorption of nutrients onto the cell surface;
- 4) Cell metabolism;
- 5) Desorption of waste products;
- 6) Diffusion of waste products from the matrix interior to the biofilm surface; and
- 7) Mass transfer of waste products from the biofilm surface to the bulk liquid.

Predominantly aerobic conditions prevail in the first reaction cell. Besides supporting the growth of an aerobic biofilm habitat, the lower oxidation level nitrogen forms (*e.g.*, ammonia) are oxidized by *Nitrosomonas* bacteria. Assimilative reduction of nitrate then takes place in the downstream reaction cells with reduced DO levels.

4.6.2 Summary of Investigation Results

The results obtained suggest that the overall phosphorus removal efficiency of the BTI technology is relatively low.

4.6.3 Conclusions and Recommendations

Due to its relatively low Total P removal efficiency, the BTI developed treatment technology is not recommended for further considerations.

4.7 MICROFILTRATION (ZENON Environmental, Inc.)

The “microfiltration” (MF) process is a membrane solids separation technique that can be used to remove suspended solids, large macromolecular materials, bacteria, and algae from a large variety of raw water sources. The ZENON Environmental Inc.-supplied MF unit was operated from October 1, 1999 to November 30, 1999.

4.7.1 Process Description

The pilot unit uses hollow fibers to remove particles greater than 0.1 micron from a feed stream. Individual fibers are bound together in a ‘membrane cassette’, with each cassette containing a total of 150 square feet of filter membrane surface area. A total of three cassettes are housed in the unit. The membranes are vertically suspended in a 370-gallon feed water tank. Feed water is pumped into the tank and a vacuum pump system draws the feed water through the membranes producing the filtrate (or permeate) stream. Compressed air is continuously pumped into the feed tank at rate of between 12 CFM to 18 CFM. The aeration keeps solids continuously mixed within the tank and reduces solids buildup near the surface of the membranes. The normal hydraulic loading range of the pilot unit is 12,000 gpd to 17,000 gpd (or 28 gpd/sq.ft. to 38 gpd/sq.ft. of membrane surface area).

The ZENON pilot unit is classified as a ‘cross-flow with concentrate recycle’ MF system. In this configuration, a significant portion of the feedwater stream passes through the membrane and is collected as permeate. The remainder of the feed stream (2 percent to 5 percent of the feed stream) is discharged directly from the system carrying with it solids constituents that have been rejected by the membranes.

When the operating pressure increases to about 18 psi, the membranes need cleaning, which can be accomplished by the simple reversal of the normal flow regime. The 8 second to 10 second cleaning procedure takes typically places every 10 minutes. The operation of the unit is PLC controlled. Periodically the unit needs longer duration cleaning with sodium hypochlorite.

4.7.2 Summary of Investigation Results

The results suggest that the MF treatment process has the potential for significant reduction of Total P concentration. In the absence of a chemical pretreatment the Total P concentration of the feed water (15 µg/L to 30 µg/L) could not be routinely reduced below the threshold limit of 10 µg/L. These findings are in agreement with those conducted by Conestoga-Rovers & Associates' (CRA) "Microfiltration Supplemental Technology Demonstration Project" (CRA Report, May 1998).

4.7.3 Conclusions and Recommendations

In the absence of a chemical pretreatment, the ZENON MF treatment unit could not routinely reduce the Total P concentration of the untreated raw water (South Test Site) below the threshold limit of 10 µg/L. These findings suggest that the ZENON treatment technology alone has limited the potential for full-scale applications. The primary objective is to achieve a 10 ppb or less Total P concentration.

4.8 BENCH SCALE FILTRATION WITH GLASS-SAND FILTER MEDIA (Syracuse University / HSA Engineers & Scientists)

Syracuse University of New York has investigated the filtration characteristics of glass-sand filter media. HSA requested and obtained some of this media for assessing its Total P removal characteristics on actual canal waters.

4.8.1 Process Description

The available glass-sand filter media was packed in two ½" diameter 2-foot high filter columns. The columns were connected in series and operated in the upflow mode. The bench scale filter columns were attached to the outside of the pilot scale clarifier in treatment trailer #1. The actual clarified water was pumped to the bench-scale filter units at an approximate feed rate of 2.45 gpm/sq.ft. of filter area. During the course of the bench scale filtration test, the pilot unit was operated with ferric-sulphate coagulant and A-130 coagulant aid.

4.8.2 Scientific Investigation Protocol

As reported by Ray Letterman of Syracuse University, the supplied media was a 50/50 mix of two washed size fractions (0.6 to 1.18 mm and 0.295 to 0.6 mm, respectively). HSA retained CRA to conduct a confirmatory sieve analysis of the size distribution of the glass-sand media. The attached results show that Syracuse University's report and CRA's confirmed results are in close agreement.

Samples for Total P analysis were taken at three distinct locations along the bench-scale treatment process: 1) incoming raw (*i.e.*, clarifier effluent) water, 2) between the two filter columns, and 3) final effluent (*i.e.*, column #2 effluent).

4.8.3 Summary of Investigation Results

The bench-scale filtration results suggest little Total P removal efficiency of the glass-sand packed filter columns. Discrete filtration results showed a nominal (<10 percent) Total P removal efficiency in the first filter column, and essentially no removal in the second column in series. In addition, the initial adjusted hydraulic filter loading of 3.45 gpm/sq.ft. dropped to almost zero in about three hours.

4.8.4 Conclusions and Recommendations

Due to the little Total P removal efficiency and the short filter run, the glass-sand filter media is not recommended for further assessment.

4.9 COATED GRANULAR MEDIA FILTRATION (University of Florida)

The University of Florida (UofF) developed and patented a technique to coat granular filter media with metallic hydroxide precipitate. Bench-scale testing results suggest that the coated filter media have enhanced phosphorus removal characteristics.

4.9.1 Process Description

HSA has collected and delivered water samples, from both the North and South Test Sites to the UofF, where the supplied water was fed to filter columns containing 1) modified sand, 2) modified carbon, and 3) modified olivine granular filter media. Each of these media was coated with a patented metallic

hydroxide precipitate. The two filtration tests took place on July 6, 1999 and September 8, 1999.

Liquid phase samples from both the incoming unfiltered raw water and the filtrate were collected. The collected samples were analyzed for Total P and orthophosphate concentrations for waters from the North and South Test Sites, respectively.

4.9.2 Scientific Investigation Protocol

Activated carbon and olivine sand media were sieved to 30-50 mesh (0.6 mm–0.3 mm). After coating with ferric and aluminum hydroxides, the coated solids were rinsed and dried. The modified granular media was placed into 2-inch diameter and 1-foot high filter columns.

After being delivered to the UofF, the HSA-collected water samples were stored at 4°C for three days. Before pumping to the filter columns, the waters were homogenized and allowed to warm to room temperature. In addition to raw water, four effluent samples were also collected from each of the downflow-operated columns throughout the filtration of 5 gallons of feed water. The collected samples were frozen and sent by UofF to PPB Laboratories (Gainesville, Florida) for analysis.

4.9.3 Summary of Investigation Results

Collected canal water samples from both of the two test sites were introduced to 2-inch diameter filter columns at rates of 7.3 gpm/sq.ft. and 18.2 gpm/sq.ft. The influent Total P concentration of 245 µg/L (North Site) was reduced to 55 µg/L and 7.5 µg/L by the modified carbon and modified olivine media, respectively. The South Test Site water orthophosphate concentration of 48 µg/L could be reduced to 11.5 µg/L by the modified sand, and 6.0 µg/L by the modified carbon media.

4.9.4 Conclusions and Recommendation

Bench-scale testing results suggest that the UofF-patented filter media have the potential for significant Total P reduction. Due to the relatively small-scale study, caution should be exercised before interpolating these data to the design of

pilot or full-scale facilities. Also, cost effective means of backwashing and regenerating the material would need to be developed.

4.10 TESTING OF SUPPLIED COAGULANT AIDS (ETUS Inc. / HSA)

ETUS Inc. supplied HSA with three coagulants for bench-scale testing. Jar test results showed little removal of Total P concentration.

4.10.1 Process Description

The three tested coagulants were:

- Eliminator C500;
- EB-LS500; and,
- EG-1.

ETUS provided HSA with a scientific investigation protocol for tests, which was followed by the HSA field team conducting jar test trials using their coagulant formulation. Jar test analyses on feed waters from both the North and South Test Sites were conducted.

4.10.2 Scientific Investigation Protocol

ETUS provided a detailed investigation protocol for the jar test trial of their coagulants. A summary of this protocol is provided below:

Procedure #1:

- 1) Take 1 cc of Eliminator C500 sample and dilute it in 1000 mL of distilled water;
- 2) Take 5 cc of this solution and add it to each of 3 different 1000 mL Everglades water samples;
- 3) Mix them at 100 RPM for 5 minutes;
- 4) Take 1 cc of EB-LS500A and add it to 1000 mL of distilled water;

- 5) Add 20 mg/L of this solution to a beaker containing 1000 mL of Everglades water. Add 25 mg/L to a second 1000 mL beaker of Everglades water. Add 30 mg/L of solution to a third 1000 mL beaker of Everglades water;
- 6) Mix each beaker for 15 minutes at 1020 RPM;
- 7) Adjust pH to 6; and,
- 8) Allow water sample to settle for 30 minutes.

Procedure #2:

- 1) Take 1 cc of EG-1, dilute with 1000 mL of distilled water;
- 2) Add 10 mg/L of this solution to a beaker containing 1000 mL of Everglades water. Add 15 mg/L to a second 1000 mL beaker of Everglades water. Add 20 mg/L of solution to a third 1000 mL beaker of Everglades water;
- 3) Mix each sample at 100 RPM for 5 minutes followed by 15 RPM mixing for 10 minutes;
- 4) Adjust pH to 6; and,
- 5) Allow water sample to settle for 30 minutes.

4.10.3 Summary of Investigation Results

Jar test results showed that the raw canal water Total P concentration of 21 µg/L (South Site) and 137 µg/L (North Site) could be reduced to 19 µg/L, and 130 µg/L, respectively. The results suggest that under the conditions tested only nominal removal of Total P concentration would be achieved by ETUS-supplied treatment chemicals.

4.10.4 Conclusions and Recommendation

Chemically assisted sedimentation test results showed that ETUS-supplied treatment chemicals would remove less than 10 percent of the raw water Total P concentration. The coagulants are not recommended for further trials.

4.11 ACTIVATED ALUMINA

HSA conducted on-site filtration tests using activated alumina as filter media to determine the adsorbent and physical filtration performance on Post-BMP waters.

4.11.1 Process Description

The filtration test was operated using a four-inch diameter, 10-foot high filter column. The filter column was packed with 30 inches of granular alumina (effective size 0.8-3.2 mm) and was supplied with untreated raw water.

4.11.2 Testing Summary

Pilot trials were conducted at the North Test Site (Post-BMP) from December 17 through December 22, 1999. The filter was operated in a declining rate mode from a starting filtration point of 2 L/min and was back-washed with filtrate when the effluent flow rate fell below approximately 1 L/min. This corresponds with a filter-loading rate of 6.0 to 3.0 gallons/min/ft². Eleven filtrate samples were collected and analyzed for Total P, SRP, and TDP. Raw water quality was obtained from the composite samplers used for the CTSS testing at the North Site.

4.11.3 Conclusion

The average feed Total P concentration to the alumina column was equal to 112 micrograms per liter, and the average filtrate Total P was equal to 99 micrograms per liter. This phosphorus reduction could be attributed to adsorptive and physical filtration. The testing results indicate that filtration with activated alumina at loading rates between 3.0 and 6.0 gallon/min/ft² alone cannot reduce Total P concentration in neutral pH Post-BMP waters to 10 ppb.

4.12 RESIDUAL SOLIDS LEACHING STUDY

HSA conducted field trials to determine if phosphorus was releasing from accumulated chemical treatment solids into the surrounding waters.

4.12.1 Process Description

Eight containers were filled with 4 liters of residual solids and 16 liters of clarified effluent water then topped. The residual solids were obtained from two test locations (North and South) and two treatment chemicals (alum and ferric chloride). Two control containers (one from the North and one from the South Test Sites) were filled with only clarified water.

Samples were collected from the water column above the residual solids periodically during the study to determine if the phosphorus concentration in the clarified water increased with time.

4.12.2 Testing Summary

From November 11, 1999 through December 17, 1999, samples of the clarified water were collected and analyzed primarily for TDP.

4.12.3 Results

A total of 27 clarified water samples were collected from the residual solids containers and eight samples were collected from the control containers.

4.12.4 Conclusion

It appears that there is no statistical difference between the initial TDP concentrations and the final TDP concentrations. Therefore, it can be concluded that no phosphorus released from the residual solids into the water column during the six-week study.



FIGURE 4.1
Photograph of:
Krüger Inc. –
Actiflo Process Trailer



FIGURE 4.2
Photograph of:
*Infilco Degremont, Inc. –
DensaDeg Process Unit*



FIGURE 4.3

Photograph of:

***ROCHEM Environmental, Inc. –
Ultrafiltration Pilot Unit (2 gpm)***



FIGURE 4.4a

Photograph of:

***F.B. Leopold Company –
Dissolved Air Flotation Trailer***



FIGURE 4.4b

Photograph of:

***F.B. Leopold Company –
DAF***

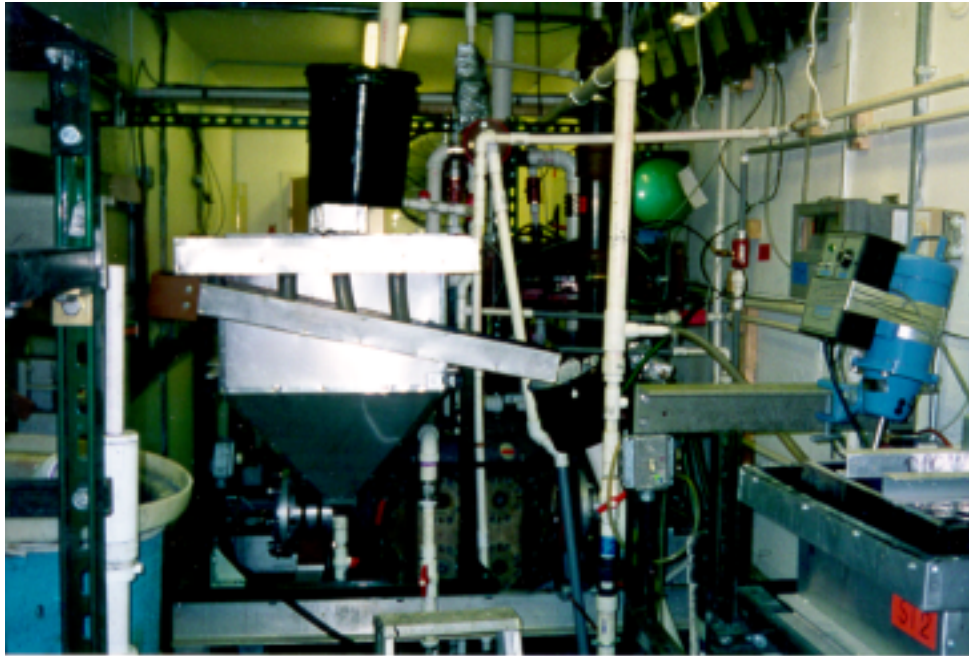


FIGURE 4.5
Photograph of:
*Micromag Corporation –
CoMag Process Mobile Pilot Units*